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RADIO ASTRONOMY OBSERVATORY

DEPARTMENT OF PHYSICS

FLORIDA STATE UNIVERSITY

TALLAHASSEE, FLORIDA

Status Report No.9 on Grant NASA-NSG-224-61

to
National Aeronautics and
Space Administration

from
Department of Physics
Florida State University
Radio Astronomy Program

Period
February 1, 1966 through July 31, 1966

Submitted by

C. H. Barrow
Principal Investigator

Abstract.

Polarization measurements and millisecond pulse studies were continued into March 1966 during the past apparition. Reception conditions have been much improved by moving the Radio Observatory to its new site.

The millisecond pulse data has been analyzed and published. It has been found that this type of Jupiter radiation is primarily associated with the B and C Sources and it is thought that interplanetary diffraction may be responsible.

Correlation and phase observations have been made at 18 Mc/s. in addition to the usual left- and right-hand components measured at this and at other frequencies. The records are still being analyzed and an approximation technique has been developed to analyze the large quantity of data involved which, at present, has to be handled manually.

A series of non-scientific set-backs has greatly impeded the program of spaced-site observations. These, hopefully, have been resolved for the 1966-7 apparition, however.

The computer programs for routine analysis of the observations have been refined and extended. A program has been written which prepares an activity prediction chart using the Io correlation. Predictions during the 1965-66 apparition were about 85% successful.

S-66 beacon satellite observations are in progress and local measurement of the integrated electron density of the ionosphere is now possible.

Data continues to be edited and microfilmed for the NASA Space Science Data Center.

1. Millisecond Pulse Experiment.

Baart, Barrow, and Lee have conducted an experiment to observe, to identify conclusively, and to study the relationship to normal radiation of the very short pulses (less than 50 millisecond) that have been observed in the decametric radiation from Jupiter. These have arbitrarily been called I-pulses.

Observations were made at 14, 16, 18, 22, and 26 Mc/s. Left- and right-hand components were measured at 16, 18, and 22 Mc/s. and total power observations were made at 14 and 26 Mc/s. A null antenna with zero reception in the direction of Jupiter and a phase-switched interferometer were used as additional identification aids at 18 Mc/s. Considerable attention was given to the problem of unambiguous identification of the pulses and also to obtaining the best possible overall time characteristics for the equipment available. Measurement indicated that pulse durations down to 7 milliseconds could be detected and their left- and right-hand components measured.

Out of a total of 92 events observed during the past apparition, 18 contained a considerable amount of I-pulse activity. The data has been analyzed and a detailed account has been published. ["Millisecond Radio Pulses from Jupiter," E. E. Baart, C. H. Barrow, R. T. Lee. Nature, 211, 808 (1966)].

The main features of this experiment are:-

1. Axial ratio measurements (assuming 100% polarization)

show that I-pulse polarization is generally similar to that of the normal radiation.

2. The main source A peak is not present in the histogram while the subsidiary sources B and C and the D null region are as well shown as in most general observations.

3. A possible explanation is that radiation associated with the B and C sources is produced within a smaller region than that from source A and so gives rise to a finer diffraction pattern in the interplanetary medium. I-pulses may be present at one frequency and not at another and this may be an indication of the different depths and hence sizes of the source regions in the Jovian magnetosphere at which the different frequencies are produced.

4. So far the Io correlation appears to be more clearly indicated for events containing I-pulses than for other events.

It is interesting to note that some other types of Jupiter radiation also show the absence of the main source A. Examples are indicated in Figure 1. While the millisecond pulses all showed a definite polarization there did not appear to be any systematic tendency for either left- or right-handed pulses to predominate. In other words, the millisecond-type pulses and the left-handed polarization may be independent characterisitcs of the B and C sources. Further study of the pecularities of these sources, particularly at low frequencies, may well prove to be a rewarding approach for the future. (See Section 8 on Future Plans.)

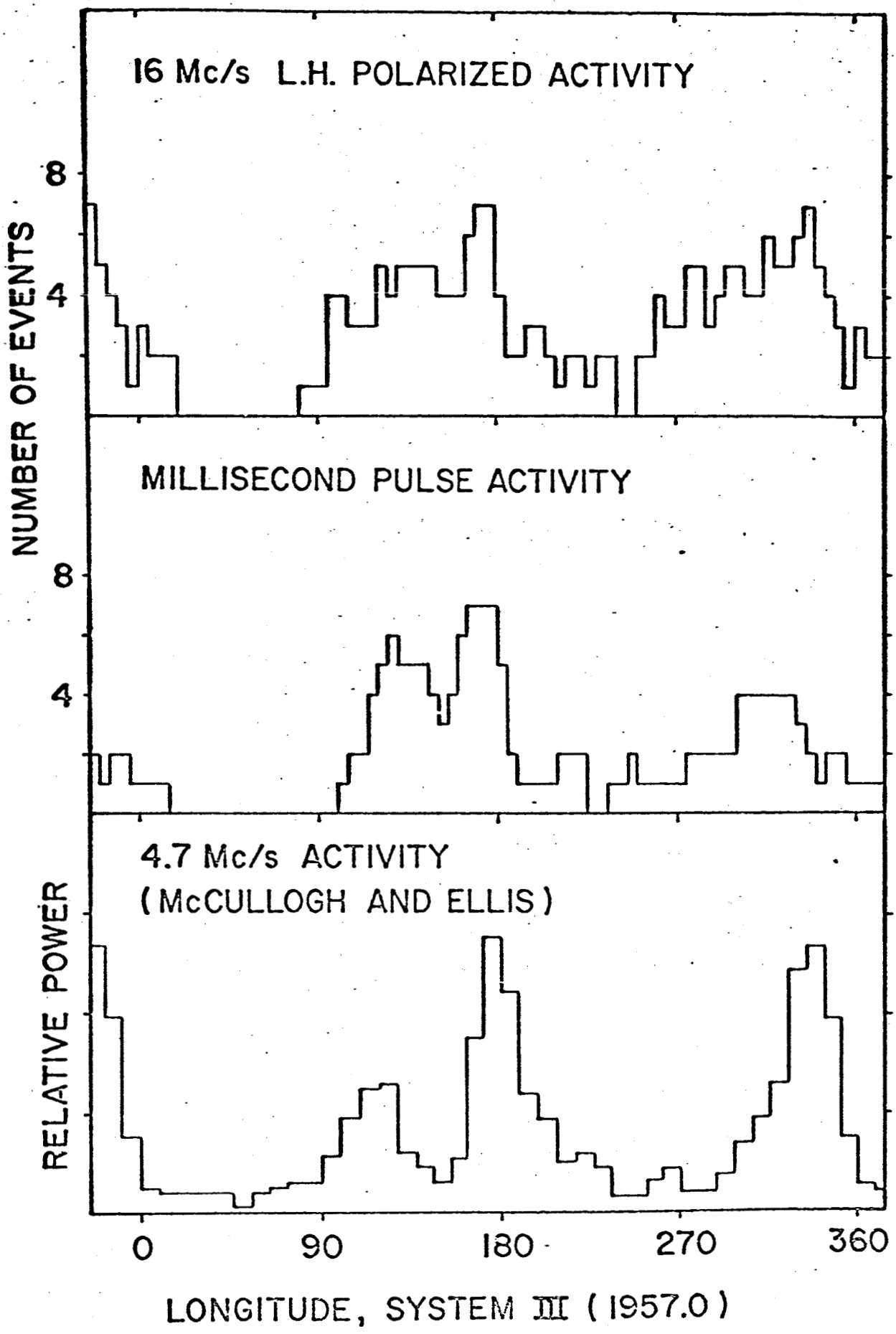
16 Mc/s L.H. POLARIZED ACTIVITY
NUMBER OF EVENTS
8
4
MILLISECOND PULSE ACTIVITY
8
4
4.7 Mc/s ACTIVITY
(McCULLOGH AND ELLIS)
RELATIVE POWER
0
90
180
270
360
LONGITUDE, SYSTEM III (1957.0)

Figure 1.

2. Polarization Measurement.

All four parameters of Jovian radiation were measured at 18 Mc/s. during the 1965-66 apparition. The overall time characteristics of the polarimeter system permitted burst durations of less than one second to be distinguished. Improved statistics could therefore be obtained, if required, by increasing the recorder speed but manual analysis of the resulting volume of data was extremely time consuming. Morrow and Barrow have developed an approximation technique the results of which have been compared with a more complete analysis for selected events using normalized distribution of axial ratio and polarization fraction. It has been found that the general form of the distribution can be preserved in approximation and that the time saved is considerable.

Calibration proved to be complicated as the polarimeter detectors* were found to be midway between linear and square-law with a low-intensity threshold. The best results so far have been obtained by using a least squares fit of the calibration points on a log-log plot and standardizing each channel of the electronics to a separate curve before each period of observation.

3. Radio Beacon Satellite Observations.

Radio beacon satellite observations have been initiated in order to determine more completely the local effects of the

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*Custom made by Aerospace Research Incorporated.

terrestrial ionosphere on the Jupiter radiation. The observation program is now underway and some data has been obtained. A continuous watch is to be established during the next Jupiter apparition.

Two satellites, the 1964-64A/BE-B and the 1965-32A/BE-C, are to be monitored at Tallahassee. Both satellites are in near-circular orbits with nominal altitudes of 1000 kilometers, that is, above the major portion of the ionosphere. Transmitters aboard the satellites radiation coherent, unmodulated, linearly polarized, CW signals at 20 Mc/s., 40 Mc/s., 41 Mc/s., and 360 Mc/s.

The 40 Mc/s. and 41 Mc/s. transmissions are being monitored in what is known as the 'closely spaced frequency method.' If the observer uses two plane polarized receiving antennas, one for each of the two frequencies, a record will be obtained showing a periodic fluctuation of signal strength as the plane of polarization of the radiation is Faraday rotated with respect to the antennas. The rotation rate is different for the two frequencies and a comparison of the resulting records allows the integrated electron density to be determined.

4. Computing.

A prediction program has been written utilizing the Io correlation effect. Typical outputs from the program for December, 1966 are shown in Figures 2 and 3.

In the chart, the 'X's represent the Universal Times of

coincidence of Io positions between 70° - 110° and System III longitudes between 100° - 180°. The 'O's represent the Universal Times of coincidences of Io positions between 220° - 260° and System III longitudes between 210° - 350°. The table following the graph gives the exact Universal Times of the coincidences.

The standard histogram program has been rewritten to expand the quantity of data it is capable of handling and to present the results graphically. Also the program will now produce histograms of occurrence probability versus the departure of the moon Io from superior geocentric conjunction.

5. Editing of Records for Microfilming.

Microfilm copies of all records are being supplied to the NASA Space Science Data Center. The last batch of data was copied in August, 1965. Since that time the following records have been edited for microfilming:- 1962, 1963, and 1965-66 slow-speed records, and Brush high-speed records from 1962, 1963, and 1964 polarization observations.

Very high-speed Brush recordings, made during the 1965-66 apparition of Jupiter at Tallahassee in the course of the I-pulse experiment, present somewhat of a problem for copying. The possibility of copying these continuously on 16 mm. movie film is being investigated.

Another "Catalogue of Jupiter Activity" will be prepared, in due course, for observations made in 1965 through 1967.

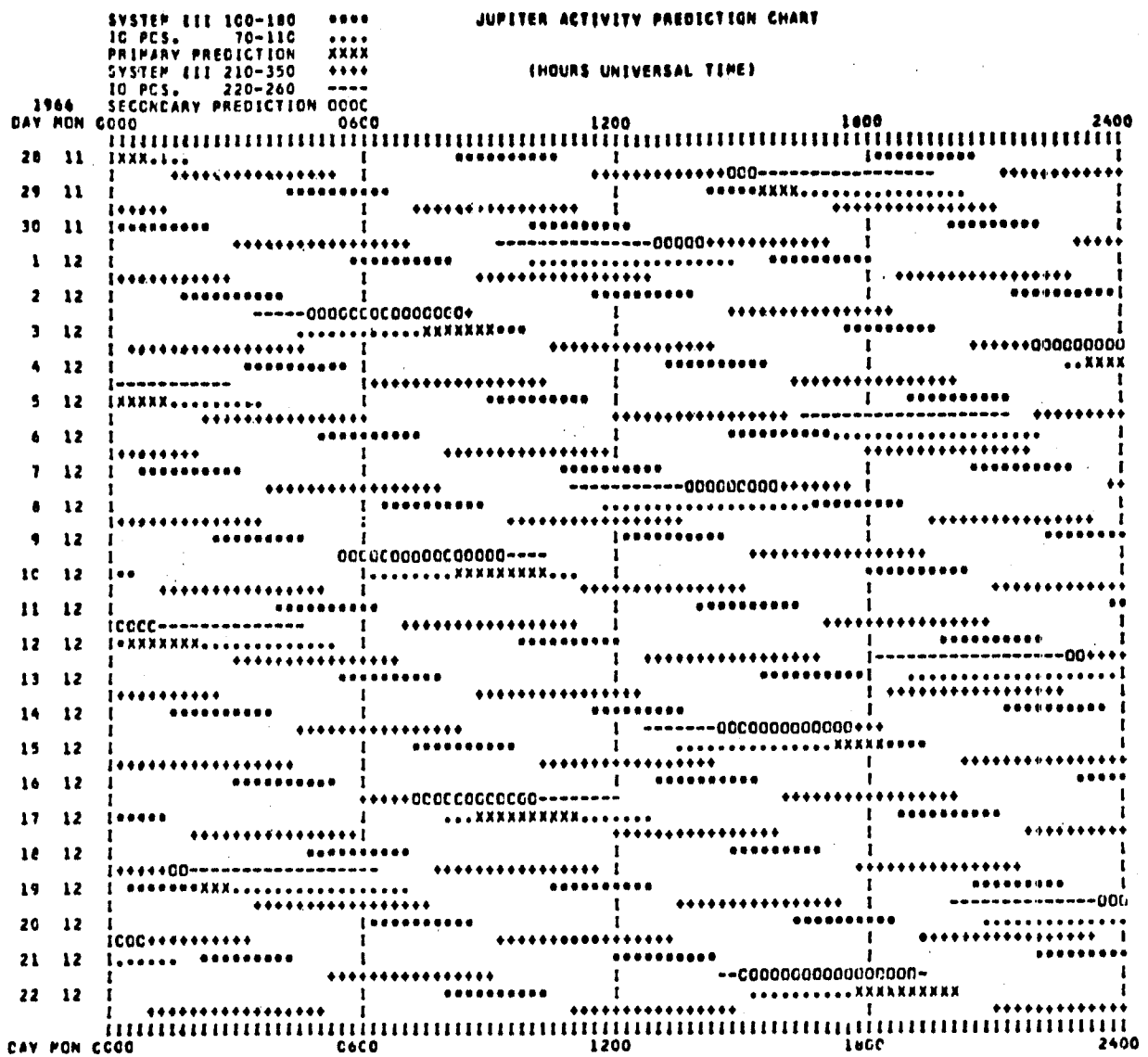
SYSTEM III 100-180 ••••
IO PCS. 70-110 ....
PRIMARY PREDICTION XXXX
SYSTEM III 210-350 ++++
IO PCS. 220-260 ----
SECONDARY PREDICTION OOOO
JUPITER ACTIVITY PREDICTION CHART
(HOURS UNIVERSAL TIME)
1966
DAY MON 0000
0600
1200
1800
2400
28 11
29 11
30 11
1 12
2 12
3 12
4 12
5 12
6 12
7 12
8 12
9 12
10 12
11 12
12 12
13 12
14 12
15 12
16 12
17 12
18 12
19 12
20 12
21 12
22 12
DAY MON 0000
0600
1200
1800
2400

Figure 2.

JUPITER ACTIVITY PREDICTION TABLE

(HOURS AND MINUTES UNIVERSAL TIME)

1966		LAMBDA III 100-180		LAMBDA III 210-350		LAMBDA III 100-180		LAMBDA III 210-350		LAMBDA III 100-180		LAMBDA III 210-350		IO POSITION 70-110		IO POSITION 220-260		IO POSITION 70-110	
28	11	0000	0039	0128	0520	0822	1034	1124	1515	1817	2030	2119	2400	0000	0144	1444	1927	0000	0000
29	11	0413	0625	0000	0111	1408	1621	0715	1106	0000	0000	1710	2102	0000	0000	0000	0000	1529	2013
30	11	0003	0216	0305	0657	0959	1211	1301	1652	1954	2207	2256	2400	0000	0000	0910	1353	0000	0000
1	12	0556	0802	0000	0248	1545	1758	0852	1243	0000	0000	1847	2239	0000	0000	0000	0000	0955	1439
2	12	0141	0353	0443	0834	1136	1348	1438	1830	2132	2344	0000	0000	0000	0000	0336	0820	0000	0000
3	12	0727	0939	0033	0425	1722	1935	1029	1420	0000	0000	2024	2400	0422	0906	2205	2400	0000	0000
4	12	0318	0530	0000	0016	1313	1526	0620	1011	2309	2400	1615	2007	0000	0000	0000	0247	2251	2400
5	12	0000	0121	0211	0602	0904	1116	1206	1558	1900	2112	2202	2400	0000	0333	1632	2116	0000	0000
6	12	0455	0707	0000	0153	1450	1703	0757	1148	0000	0000	1752	2144	0000	0000	0000	0000	1718	2201
7	12	0046	0258	0348	0739	1041	1253	1343	1735	2037	2249	2339	2400	0000	0000	1058	1541	0000	0000
8	12	0632	0844	0000	0330	1627	1840	0934	1325	0000	0000	1929	2321	0000	0000	0000	0000	1144	1627
9	12	0223	0435	0525	0916	1218	1431	1520	1912	2214	2400	0000	0000	0000	0000	0525	1008	0000	0000
10	12	0000	0026	0115	0507	0809	1021	1111	1502	1804	2017	2106	2400	0610	1053	2353	2400	0000	0000
11	12	0400	0612	0000	0058	1355	1608	0702	1053	2351	2400	1657	2049	0000	0000	0000	0434	0000	0000
12	12	0000	0203	0253	0644	0946	1158	1248	1640	1942	2154	2244	2400	0036	0519	1818	2302	0000	0000
13	12	0537	0749	0000	0235	1532	1745	0839	1230	0000	0000	1834	2226	0000	0000	0000	0000	1905	2348
14	12	0128	0340	0430	0821	1123	1335	1425	1817	2119	2331	0000	0000	0000	0000	0000	0000	0000	0000
15	12	0714	0926	0020	0412	1709	1922	1016	1407	0000	0000	2011	2400	0000	0000	0000	0000	1245	1729
16	12	0305	0517	0000	0003	1300	1512	0607	0958	2256	2400	1602	1954	0000	0000	0711	1154	1331	1814
17	12	0000	0108	0157	0549	0851	1103	1153	1545	1846	2059	2148	2400	0756	1240	0000	0000	0000	0000
18	12	0442	0654	0000	0140	1437	1650	0744	1135	0000	0000	1739	2131	0000	0000	0137	0620	0000	0000
19	12	0032	0245	0334	0726	1028	1240	1330	1721	2023	2236	2325	2400	0222	0705	2005	2400	0000	0000
20	12	0619	0831	0000	0317	1614	1826	0921	1312	0000	0000	1916	2308	0000	0000	0000	0046	2051	2400
21	12	0209	0422	0511	0903	1205	1417	1507	1858	2200	2400	0000	0000	0000	0132	1431	1914	0000	0000
22	12	0000	0013	0102	0454	0756	1009	1058	1449	1751	2004	2053	2400	0000	0000	0000	0000	1516	2000

DAY	MON	PRIMARY PREDICTION BEGIN	PRIMARY PREDICTION END	SECONDARY PREDICTION BEGIN	SECONDARY PREDICTION END
28	11	0001	0039	1444	1515
29	11	1529	1621	0000	0000
30	11	0000	0000	1301	1353
2	12	0000	0000	0443	0820
3	12	0727	0906	2205	2400
4	12	2309	2400	0001	0016
5	12	0001	0121	0000	0000
7	12	0000	0000	1343	1541
9	12	0000	0000	0525	0916
10	12	0809	1021	2353	2400
11	12	0000	0000	0001	0058
12	12	0036	0203	2244	2302
14	12	0000	0000	1425	1729
15	12	1709	1814	0000	0000
16	12	0000	0000	0711	0958
17	12	0851	1103	0000	0000
18	12	0000	0000	0137	0140
19	12	0222	0245	2325	2400
20	12	0000	0000	0001	0046
21	12	0000	0000	1507	1858
22	12	1751	2000	0000	0000

Figure 3.

6. Spaced-Site Observations.

The North-South line of stations has produced data in both the 1964-5 and 1965-6 apparitions. However, the observations required have yet to be achieved. During the first apparition funds were not available for high-speed recorders at any station and although simultaneous observations were obtained it was not possible to say anything about the burst structures seen at each site. During the second apparition a small high-speed recorder was added to each station but various set-backs occurred which prevented all five stations being active at any one time throughout the period. These were:-

Trondheim, Norway - snowstorms damaged antenna on two occasions

Valencia, Spain - High-speed recorder delivered late and further delayed in customs until about the last two weeks of observations.

Ibadan, Nigeria - High-speed recorder motor burnt out in first week of use. Repaired locally, unsatisfactory operation and then burnt out again. Not available for any of apparition.

Grahamstown, South Africa - Bush fire damaged feedlines and antenna.

St. Osyth, England - Operated continuously throughout apparition.

It is hoped that all stations will be properly operative for all of the coming apparition. Local directors have already been advised of slight modifications and improvements to technique and have been asked to request replacements, etc., in good time. Observations are to start on October 1, 1966.

As our first interest is in individual events observed

simultaneously and under standardized observing conditions rather than long period statistics, the prediction system is to be used during the coming apparition. Trondheim, St. Osyth, and Grahamstown (which have proved to be the most efficiently operated stations so far) will continue to observe the entire period. Ibadan and Valencia, however, will observe only on predicted nights. This will also help to conserve operating funds to some extent.

7. Difficulties.

The problems encountered in the spaced-site experiment have already been outlined in Section 6. In addition to these, the project has been considerably delayed by its dealings with Aerospace Research, Inc., who manufactured the polarimeter electronics and the phase-switches and supplied two riometers. Delivery dates of the custom made equipment were several months late and only one of seven items ordered arrived in perfect operational order. In some cases the faults were relatively small, in most cases they indicated inadequate check-out procedures prior to shipment. The correction of these faults by Aerospace has proved to be a time consuming business and the two riometers are still inoperative. The service provided by the manufacturers has not been impressive.

8. Future Plans.

The millisecond pulse experiment has provided some interesting and provocative results during the past apparition. An obvious extension of this experiment would be to improve the overall time resolution and this could easily be achieved by the use of a high-speed camera with an oscilloscope display of the pulses. Using a dual beam oscilloscope it should be possible to photograph the left- and right-hand components of I-pulses down to less than 1 millisecond in duration. This would be entirely new in the study of Jupiter. It is doubtful if lengthy statistics from this type of experiment would be profitable in terms of time involved in analysis and information produced, unless the entire process could be automated. Samples from representative events would, however, be very interesting to study.

The planet Saturn is beginning to move to a more northerly declination and will soon be observable with the Arecibo radio telescope. In view of the many similarities of Jupiter and Saturn, as well as the fact that Saturn has on one or two occasions been suspected by several different workers of radiating at decameter-wave frequencies, it would be important to study this planet with a sensitive antenna system in an attempt to identify such emission conclusively. It has been shown by Stone, Alexander, and Erickson using the Clark Lake 26.3 Mc/s. antenna that increased sensitivity gives rise to a spectacular increase in the amount of Jovian activity observed.

Consequently, tentative arrangements have been made to conduct a search for radio emissions from Saturn at the Arecibo Ionospheric Observatory when Saturn is well placed for night-time observation. July, August, and September of 1967 would be the next occasion. Interference from a neighboring power-line has been causing some trouble at Arecibo recently but plans have been made to replace the present insulators on the line and observations should be possible when this has been done.

The St. Osyth station in England is participating in an experiment with Hewish's group at Cambridge University. An attempt is being made to study the motion of the interplanetary medium by spaced-site observations at 81 Mc/s. Three antennas, along a roughly equilateral triangle of side approximately 65 miles, are being used simultaneously to monitor 3C48. The data is transmitted by telephone lines to the Mullard Radio Observatory at Cambridge. There is also a conventional chart record made at each station. The antenna sensitivity is about 20×10^{-26} wats. $m^{-2}.(c/s)^{-1}$ and consists of 108 dipoles connected in the form of a phase-switched grating system.

Gruber (Rhodes University) has recently made the prediction* that harmonics exist in Jupiter radiation at 18, 27, 36. . .Mc/s., etc. This is based upon a statistical study of his own and the High Altitude Observatory data during the past five years. 81 Mc/s. is a higher harmonic in this series. It is proposed, therefore, to monitor Jupiter with the St. Osyth 81 Mc/s. antenna

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*Ph.D. Thesis, Rhodes University and paper submitted to the Astrophysical Journal.

during the coming apparition. It should be pointed out, however, that the fringe system of the antenna is such that only about 10 minutes of observing time is available each night. Also that, according to Gruber, even harmonics are more favorable than odd harmonics. However, it is felt that the opportunity to use such a sensitive system on Jupiter should not be missed.

Resch has worked at Clark Lake Radio Observatory during the summer and with Erickson (University of Maryland) has constructed a large fringe-sweeping 80 dipole antenna at 26.3 Mc/s. This is to be used in an attempt to detect motion of the Jovian source across the disc and solar emission during flare activity. Resch also hopes to be able to measure the emission velocities of the particles during flare activity. This is an extension of the study of Solar-Jupiter relationships conducted for his M.S. Thesis. This project is being undertaken with the University of Maryland who have sponsored the antenna.

A proposal has been submitted to the National Science Foundation for an equipment grant to enable the Jupiter burst data to be digitized and analyzed by the computer without the intermediate manual procedure at present necessary. The result of this proposal is not likely to be known for some time yet. As an interim measure a four-track Sanborn FM magnetic data recorder has been purchased from Grant Funds, instead of further high-speed pen recorders, so that polarimeter data may be stored on tape and hopefully digitized in the future, either at Tallahassee or with borrowed facilities elsewhere.

9. Publications February 1, through July 31, 1966.

"Millisecond Radio Pulses from Jupiter."
Baart, E. E., Barrow, C. H., Lee, R. T.
Nature, 211, 808 (1966).

"Millisecond Pulses in Jupiter Radiation." (Abstract)
Baart, E. E., Barrow, C. H., Lee, R. T.
Astron. J. 71, 377 (1966).

"A Study of the Millisecond Pulses Contained in the Decametric Radiation from Jupiter."
Lee, R. T.
M.S. Thesis, Florida State University, July 1966.

"Polarization of the Jupiter Radiation." (Abstract)
Barrow, C. H., Baart, E. E., Morrow, D. P.
Proceedings of the URSI-USNC Meeting, Washington, D.C., April 1966.

"A Catalogue of Jupiter Activity, 1961-1964." (Abstract)
Morrow, D. P. and Barrow, C. H.
Bulletin of the American Physical Society, Series II, 11, 512 (1966).

"Solar-Jupiter Relationships." (Abstract)
Resch, G. M. and Barrow, C. H.
Bulletin of the American Physical Society, Series II, 11, 512 (1966).

"Some Characteristics of the B and C Sources of Jovian Decametric Radiation."
Barrow, C. H. and Baart, E. E.
Astron. J. (Abstract in press).

Talks Given During the Period.

"Polarization of the Jupiter Radiation."
Barrow, C. H., Baart, E. E., Morrow, D. P.
URSI-USNC Meeting, Washington, D. C., April, 1966.

"Millisecond Pulses in Jupiter Radiation."
Baart, E. E., Barrow, C. H., Lee, R. T.
American Astronomical Society Meeting, Hampton, Virginia, March, 1966.

"Some Characteristics of the B and C Sources of Jovian Decametric Radiation."
Barrow, C. H. and Baart, E. E.
American Astronomical Society Meeting, Ithaca, N.Y., July, 1966.
(Read by title as Airlines strike prevented attendance by authors).

Three papers presented at the Florida Academy of Sciences Meeting, St. Petersburg, Florida, March, 1966.

"Progress Report on Jupiter Observations for Florida State University."
Hyde, F. W.
British Astronomical Association Meeting, London, England, May, 1966.

"Progress in the Observations of Jupiter."
Hyde, F. W.
"Sky at Night Programme," (ed. P. Moore)
BBC Television, London, England, January 1966.
(Not previously reported.)

"Progress in Radio Astronomy."
Hyde, F. W.
Colloquim, Southend College of Technology, England.
January, 1966. (Not previously reported).

In Preparation.

"Measurement of Four Parameters of Polarization."
Morrow, D. P.
M.S. Thesis, Florida State University.

"The B and C Sources on Jupiter."
Barrow, C. H. and Baart, E. E.
Letter to be submitted to Nature.

Paper for joint S.E.A.P.S./A.P.S. Meeting,
Nashville, Tennessee, December, 1966.

10. Personnel.

Dr. E. E. Baart returned to South Africa in June, 1966. Laboratorieingenior I. Halvard Torgersen has been appointed to a Research Associateship for the Academic Year 1966-7. He is to arrive during August. Mr. Torgersen has operated the Trondheim station for the past two years.

There are seven graduate students presently working on the project. Two of these are Ph.D. candidates, four are M.S. candidates and one is employed as Computer Programmer while being an M.S. candidate in Mathematics. Resch received the degree of

M.S. in December, 1965. Lee and Morrow hope to receive M.S. degrees in August, 1966. Morrow is writing an account of the four-parameter polarimeter experiment and is establishing a compromise procedure for examining the vast amount of data on the records and transferring this information to computer cards.

The Principal Investigator is also acting as External Examiner for Mr. G. M. Gruber's Ph.D. examination at Rhodes University, South Africa.

I. Personnel Working on the Grant.

(A.) Tallahassee

C. H. Barrow, Assistant Professor and Principal Investigator.

*E. E. Baart, Visiting Carnegie Fellow.

Graduate Assistants

L. Capone
R. T. Lee
D. P. Morrow
G. M. Resch
D. L. Thompson
J. R. Williams
J. D. Merritt

B. L. Brown, Secretary

Undergraduate Assistants

*G. R. Adcock, *C. Beagles, B. Dow, C. Falaney, *R. Gingras, *J. Herr, L. Joeris, D. Munro, B. Rosenblatt, C. Wurst, J. Van Pelt.

*Terminated during the period.

(B.) St. Osyth

F. W. Hyde, Radio Engineer and Director of St. Osyth Station (Self supported).

Technical Assistants

F. Cooper
R. Hawkins
P. Lundburg
J. Slatter

D. Crosswell, Part-time secretary

II. Personnel Associated with the Project.

(A.) Grahamstown, South Africa

E. E. Baart, Senior Lecturer in Physics and Director of Radio Astronomy.

G. M. Gruber, Lecturer in Physics
P. J. Harvey, Graduate Assistant
P. Terry, Graduate Assistant

(B.) Local Supervisors for the 1965 spaced-site observations.

S. E. Okoye, Lecturer in Physics, University of Ibadan.

J. Catala, Professor of Physics, University of Valencia.

H. Torgersen, Engineer, Technical University of Trondheim.

R. W. H. Wright, Professor of Physics, University of the West Indies.

Groups of from 3 to 5 undergraduate assistants were employed on the Grant at St. Osyth, Ibadan, Valencia, Trondheim, and Grahamstown during the period September 1, 1965 through February 28, 1966.